

What is claimed is:

1. A method of preparing percarbonic acid or a composition comprising same, the method comprising the step of contacting hydrogen peroxide and carbon dioxide under conditions conducive to formation of percarbonic acid.
2. The method of claims 1, wherein the hydrogen peroxide is an aqueous hydrogen peroxide solution.
3. The method of claim 2, wherein the aqueous hydrogen peroxide solution comprises between about 1 and about 65% hydrogen peroxide by weight.
4. The method of claim 2, wherein the aqueous hydrogen peroxide solution comprises between about 30 and about 40% hydrogen peroxide by weight.
5. The method of claim 1, wherein the hydrogen peroxide and carbon dioxide are contacted in the presence of a plasma.
6. The method of claim 1, wherein the hydrogen peroxide and carbon dioxide are contacted in the presence of UV radiation.
7. The method of claim 1, wherein the hydrogen peroxide and carbon dioxide are contacted in the presence of a plasma and UV radiation.
8. The method of any one of claims 5 to 7, wherein the hydrogen peroxide and carbon dioxide are contacted at a temperature of between about 5 and 200°C and a pressure of between 4 and 10 MPa.
9. The method of claim 2, wherein the aqueous solution of hydrogen peroxide is contacted with liquid or supercritical carbon dioxide under conditions conducive to formation of percarbonic acid.
10. The method of claim 9, wherein the aqueous hydrogen peroxide is contacted with supercritical carbon dioxide.

11. The method of claim 10, wherein the aqueous hydrogen peroxide is contacted with supercritical carbon dioxide at a temperature of between about 32 and 100°C and a pressure of between 7.6 and 35MPa.
12. The method of claim 9, wherein the aqueous hydrogen peroxide is contacted with liquid carbon dioxide.
13. The method of claim 12, wherein the aqueous hydrogen peroxide and carbon dioxide are contacted at a temperature of between about 5 and 30°C and a pressure of between 4.5 and 10MPa.
14. The method of claim 9, wherein the aqueous solution of hydrogen peroxide is contacted with liquid or supercritical carbon dioxide in a continuous flow extraction apparatus.
15. Use of a fluid comprising percarbonic acid as a cleaning agent for removing organic or biological contaminants from a substrate.
16. Use of a fluid comprising percarbonic acid and carbon dioxide as a cleaning agent for removing organic or biological contaminants from a substrate.
17. Use of a fluid comprising percarbonic acid as at least one of a cleaning, disinfecting, or sterilizing agent for cleaning, disinfecting or sterilizing a substrate.
18. Use of a fluid comprising percarbonic acid and carbon dioxide as a sterilizing agent for sterilizing a substrate.
19. Use of a fluid comprising percarbonic acid as a cleaning and sterilizing agent for removing organic, inorganic, particulate, or biological contaminants from a substrate and sterilizing same.

20. Use of a fluid comprising percarbonic acid and carbon dioxide as a cleaning and sterilizing agent for removing organic or biological contaminants from a substrate and sterilizing same.

21. A method of treating a substrate, the method comprising the step of contacting the substrate with a fluid comprising percarbonic acid under conditions conducive to substrate treatment.

22. The method of claim 21, wherein the method of treating a substrate is a method of cleaning a substrate and wherein the substrate is contacted with the fluid comprising percarbonic acid under conditions conducive to removing contaminants from the substrate.

23. The method of claim 21, wherein the method of treating a substrate is a method of sterilizing a substrate and wherein the substrate is contacted with the fluid comprising percarbonic acid under conditions conducive to sterilizing the substrate.

24. The method of claim 21, wherein the method of treating a substrate is a method of modifying the substrate, and wherein the substrate is contacted with the fluid comprising percarbonic acid under conditions conducive to substrate modification.

25. The method of claim 24, wherein the method of modifying a substrate is a method of oxidizing the surface of the substrate, and wherein the substrate is contacted with the fluid comprising percarbonic acid under conditions conducive to surface oxidation.

26. A method of cleaning a substrate, the method comprising the step of contacting a substrate with a fluid comprising percarbonic acid under conditions conducive to removing contaminants from the substrate.

27. The method of claim 26, wherein the contaminants are at least one of biological, organic, inorganic or particulate residues.

28. A method of sterilizing a substrate, the method comprising the step of contacting a substrate with a fluid comprising percarbonic acid under conditions conducive to sterilizing the substrate.

29. A method of cleaning and sterilizing a substrate, the method comprising the step of contacting a substrate with a fluid comprising percarbonic acid under conditions conducive to removing contaminants from the substrate and conducive to sterilizing the substrate.

30. The method of claim 29, wherein the method disinfects the substrate.

31. The method of claim 29, wherein the contaminants are biological, organic, inorganic, or particulate residues.

32. The method of claim 26 or 29, wherein substantially all of the contaminants are removed from the substrate.

33. The method of any one of claims 26-31, wherein the fluid comprises percarbonic acid and carbon dioxide.

34. The method of claim 33, wherein the fluid comprises liquid or supercritical carbon dioxide.

35. The method of any one of claims 26-33, wherein the fluid and the substrate are contacted with a plasma.

36. The method of claim 35, wherein the plasma is an weakly ionized plasma.

37. The method of claim 36, wherein the weakly ionized plasma is generated by a single Rf source.

38. The method of claim 36, wherein the plasma has a pressure of between about 1 and about 600 Torr.

39. The method of claim 35, wherein the plasma is an UV irradiated and weakly ionized plasma.

40. The method of claim 39, wherein the plasma has a pressure of between 0.1 atmospheres and about 2 atmospheres.

41. The method of any one of claims 26-33, wherein the fluid and the substrate are irradiated with UV light during at least a portion of the contacting step.

42. The method of claim 41, wherein at least about 40% of the UV irradiation has a wave length of less than 300 nm.

43. The method of claim 41, wherein the UV irradiation comprises between about 25-75% light having a wavelength of less than 300 nm, between about 5-40% light having a wavelength of between about 300 nm and about 750 nm, and about 5-40% light having a wavelength of at least about 750 nm.

44. The method of claim 41, wherein the UV irradiation is between about 50 to about 1500 watts.

45. The method of claim 41, wherein the UV irradiation is continuous or intermittent.

46. The method of claim 45, wherein the intermittent UV irradiation comprises pulsed UV irradiation of between about 1 and about 45 seconds per minute.

47. The method of claim 45, wherein the intermittent UV irradiation comprises pulsed UV irradiation of between about 20 and 40 seconds per minute.

48. The method of claim 45, wherein the UV irradiation is continuous.

49. The method of any one of claims 26-31, wherein the contacting step is conducted at between about 5°C and about 200 °C.

50. The method of any one of claims 26-31, wherein the percarbonic acid has a concentration of about 1 ppm to about 10,000 ppm.

51. The method of claim 50, wherein the percarbonic acid concentration is between about 10 and about 5,000 ppm.

52. The method of any one of claims 26-31, wherein the fluid further comprises at least one additive.

53. The method of claim 52, wherein the additive is selected from the group consisting of inert gases, ozone, nitrogen, noble gases, carbon monoxide, carbon tetrachloride, carbon tetrafluoride, and mixtures thereof.

54. The method of any one of claims 26-31, wherein the substrate is translated in at least one direction during at least a portion of the contacting step.

55. The method of claim 54, wherein the substrate is translated in at least two dimensions during at least a portion of the contacting step.

56. The method of any one of claims 26-31, wherein the substrate is contacted with the fluid comprising percarbonic acid for between about 1 minute and about 8 hours.

57. The method of claim 56, wherein the substrate is contacted with the fluid comprising percarbonic acid for between about 1 minute and about 2 hours.

58. The method of any one of claims 26-31, wherein the method further comprises the step of drying the substrate after contacting the substrate with the fluid.

59. The method of any one of claims 26-31, wherein the substrate is composed of a metal, a ceramic, a glass, a polymer or a combination thereof.

60. The method of claim 59, wherein the substrate is composed of stainless steel, platinum, iridium, palladium, nickel, gold, titanium, zirconium, inconel, cobalt steel, aluminum, copper, zinc, bronze, metal plating, metal foams, magnetic substrates, or combinations thereof.

61. The method of claim 59, wherein the substrate is composed of polypropylene, neoprene, Buna-N, Butyl Rubber, silicones, Viton, EPDM, polyurethane, polyetheretherketone, nylon, Teflon, Tyvek, biocompatible fabrics and polymers, cellulose acetates, PVC, CPVC, polycarbonate, Delrin, polyetherimide, polyamide, polyimide, and combinations thereof.

62. The method of claim 59, wherein the substrate is silicon dioxide, borosilicate, quartz, alumina, silica, borosilicate, zirconium oxide, silicon carbide, boron nitride, magnetic ceramics, superconductive ceramics, or a combination thereof.

63. The method of any one of claims 26-31, wherein the substrate is a medical device, a biomedical implant, a semiconductor wafer, an electronic device, or optical element.

64. The method of claim 63, wherein the substrate is a medical device.

65. The method of claim 64, wherein the substrate is a reusable endoscope.

66. A method of cleaning a substrate comprising the steps of
applying a translational force to the substrate; and
contacting a substrate with a fluid comprising percarbonic acid under
conditions conducive to removing contaminants from the substrate.

67. A method of cleaning a substrate comprising the steps of
agitating the substrate with ultrasound; and
contacting a substrate with a fluid comprising percarbonic acid under
conditions conducive to removing contaminants from the substrate.

68. A method of cleaning a substrate comprising the steps of applying a translational force and ultrasound to the substrate; and contacting a substrate with a fluid comprising percarbonic acid under conditions conducive to removing contaminants from the substrate.

69. The method of claim 66 or claim 68, wherein the fluid is contacted with the substrate while the translational force is applied thereto.

70. The method of any one of claims 66-68, wherein the contaminants are biological, organic, inorganic, or particulate residues.

71. A method of sterilizing a substrate, the method comprising the steps of applying a translational force to the substrate; and contacting a substrate with a fluid comprising percarbonic acid under conditions conducive to sterilizing the substrate.

72. A method of disinfecting or sterilizing a substrate comprising the steps of
of
agitating the substrate with ultrasound; and
contacting a substrate with a fluid comprising percarbonic acid under conditions conducive to removing contaminants from the substrate.

73. A method of disinfecting or sterilizing a substrate comprising the steps of
of
applying a translational force and ultrasound to the substrate; and
contacting a substrate with a fluid comprising percarbonic acid under conditions conducive to removing contaminants from the substrate.

74. The method of any one of claims 71-73, wherein the fluid is contacted with the substrate while the translational force or ultrasound is applied thereto.

75. A method of cleaning and sterilizing a substrate, the method comprising the steps of
applying a translational force to the substrate; and

contacting a substrate with a fluid comprising percarbonic acid under conditions conducive to removing contaminants from the substrate and conducive to sterilizing the substrate.

76. The method of claim 75, wherein the fluid is contacted with the substrate while the translational force is applied thereto.

77. The method of claim 75, wherein the contaminants are biological, organic, inorganic, or particulate residues.

78. The method of claim 75, wherein the translational force is a centripetal or Coriolis force.

79. The method of claim 75, wherein the fluid comprises percarbonic acid and carbon dioxide.

80. The method of claim 79, wherein the fluid comprises liquid or supercritical carbon dioxide.

81. The method of claim 75, wherein the fluid and the substrate are contacted with a plasma.

82. The method of claim 81, wherein the plasma is weakly ionized plasma.

83. The method of claim 81, wherein the plasma is an UV irradiated weakly ionized plasma.

84. The method of claim 75, wherein the fluid and the substrate are irradiated with UV light during at least a portion of the contacting step.

85. The method of claim 84, wherein at least about 40% of the UV irradiation has a wave length of less than 300 nm.

86. The method of claim 85, wherein the UV irradiation comprises between about 25-75% light having a wavelength of less than 300 nm, between about 5-40% light having a wavelength of between about 300 nm and about 750 nm, and about 5-40% light having a wavelength of at least about 750 nm.

87. The method of claim 75, wherein the fluid further comprises at least one additive.

88. The method of claim 87, wherein the additive is selected from the group consisting of nitrogen, noble gases, inert gases carbon monoxide, ozone, carbon tetrachloride, carbon tetrafluoride, and mixtures thereof.

89. An apparatus for cleaning or sterilizing a substrate with percarbonic acid comprising a cleaning chamber, a UV irradiation source, an electrical field generator, a device capable of applying a translational force to the substrate, and a percarbonic acid generator or percarbonic acid source.

90. A method for monitoring *in-situ* a cleaning or sterilization method of any one of claims 26-88, the method comprising the steps of:

providing a test substrate having at least one chemical or biological contaminant deposited thereon;

measuring the UV-Vis spectrum of the test substrate prior to cleaning or sterilizing;

contacting the test substrate with the fluid comprising percarbonic acid under conditions conducive to cleaning or sterilizing the substrate;

measuring the UV-Vis spectrum of the test substrate periodically during and after contacting the test substrate with the fluid; and

comparing the periodic UV-Vis spectra against the pre-cleaning or pre-sterilizing UV-Vis spectrum to monitor the cleaning or sterilization process.